

Scalable Multifidelity Design Optimization: Next Generation Aircraft and their Impact on the Air Transportation System

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We propose to solve the challenge problem of truly integrated high-fidelity design of next generation aircraft. In particular, we propose to enable high-fidelity design exploration for NASA N+3 concepts by developing a novel multidisciplinary design optimization (MDO) capability. The NASA N+3 concepts contribute significantly towards NASA's 2025 emissions and fuel burn goals, but these concepts also require an unprecedented level of integration and fidelity in their design.

This challenge problem requires new methods for large-scale MDO and integration of a greater range of relevant disciplines with appropriate levels of fidelity. Contemporary aircraft design remains a predominantly sequential process that misses significant opportunities to exploit interdisciplinary synergies. One such overlooked synergy is the influence of real world trajectories on the wing design, and their coupling to the engine design. This is a challenging problem, because trajectory analysis requires the evaluation of many flight conditions, while wing-shape design requires high-fidelity aerodynamic and structural models. A further extension of this concept will facilitate a direct link of the aircraft design problem to objectives associated with the aircraft operator. There are currently no MDO architectures that can handle such a challenging problem. Thus far, MDO architectures have not demonstrated the ability to scale up with large numbers of disciplines and design variables. On one hand, design optimization with high-fidelity function evaluations for one or two disciplines is now feasible. On the other hand, some MDO problems have successfully been solved for large numbers of disciplines, but with low fidelity and a limited number of design variables. Thus, there is a need for new approaches that can handle a large number of design variables and disciplines, with several disciplines consisting of high-fidelity models.

To succeed in solving the challenge problem, we propose the development of a new mathematical framework that efficiently handles high-dimensional models with large numbers of disciplines. This framework relies on a new view of the mathematical MDO formulation. This results in a new approach to couple disciplinary models that automatically computes coupled sensitivities, uses these sensitivities to achieve faster convergence of the coupled analysis, and makes this more robust. In addition, the coupled sensitivities enable the use of efficient gradient-based optimization.

This new MDO approach has potential, but requires significant development to address the challenge problem. One area for further development is the

integration of multifidelity methods that automatically determine the appropriate fidelity required for each discipline. We propose an approach based on reduced modeling that integrates well with the overall MDO approach. Another area requiring a breakthrough is the optimization algorithm: although there has been much progress in parallel computing, there are currently no parallel optimization libraries that can be used on practical problems. Thus, we propose the development of a parallel nonlinearly constrained optimization algorithm that naturally fits in the proposed MDO approach.

To apply the proposed MDO approach to the N+3 aircraft design challenge, we will adapt the extensive set of aircraft design tools available within our team. These models include mission analysis, airline allocation, aircraft sizing, propulsion, aerodynamics, and structures.

This project will result in two main deliverables: 1) A general MDO approach integrated into NASA's OpenMDAO that can handle large-scale problems efficiently and 2) A study of N+3 conventional and unconventional configurations within the context of next generation airspace. These deliverables will contribute directly to the overarching goal of the NASA SFW program to drastically improve aircraft efficiency and minimize the impact of aviation on the environment.